

Claims

1. A method of processing marine magnetic data obtained by towing first and second spaced apart sensors  
5 behind a ship, the method including:  
obtaining raw magnetic gradient data from the sensors;  
determining the trend of the gradient of the ship bias detected by the sensors;  
10 subtracting the trend from the raw magnetic gradient data to obtain corrected gradient data; and  
processing the corrected gradient data to provide a data output.
- 15 2. The method of claim 1 including the step of determining an estimate of the gradient of the ship bias from the raw magnetic gradient data obtained by the sensors, and determining the trend of the gradient of the ship bias from that estimate of the gradient of the ship  
20 bias.
3. The method of claim 1 wherein the raw magnetic gradient data is calculated as the measured magnetic signal at the leading sensor less the measured magnetic  
25 signal at the trailing sensor, divided by the distance between the sensors.
4. The method of claim 1 wherein the trend of the gradient of the ship bias is determined by applying the  
30 gradient of the ship bias data to a B-Spline filter with smoothness 0.8.
5. The method of claim 1 wherein the processing comprises the application of the corrected gradient data  
35 over sample intervals, integration of the corrected gradient data into total magnetic intensity data, and application of a low pass filter to the integrated total

magnetic intensity data to provide the data output.

6. The method of claim 5 wherein the total magnetic intensity is obtained by integrating the corrected  
5 gradient data in accordance with the following equation:

$$TMI = \sum_{i=1}^N [G_c \Delta x_i(t)] + M_{stat}$$

wherein  $G_c$  is the corrected gradient data obtained after subtraction of the trend of the gradient of  
10 the ship bias from the raw gradient data, and

$M_{stat}$  is the total magnetic intensity value at a point representing the start of the survey or at a location where a survey line and a tie line cross each other.

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7. The method of claim 1 wherein the gradient of the ship bias is calculated according to the following equation:

$$20 \quad G_{bias} = \frac{M_f(x) - M_r(x)}{\Delta l} = \frac{[D(t_1) - D(t_2)] + [M_b(t_1) - M_b(t_2)]}{\Delta l}$$

where:

$$25 \quad M_f(x) = M_e(x) + D(t_1) + M_b(t_1)$$

$$M_r(x) = M_e(x) + D(t_2) + M_b(t_2)$$

where  $M_e$  is the magnetic field as measured by the front sensor and which consists of the environmental field  
30  $M_e(x)$ , diurnal variation  $D(t_1)$ , ship bias  $M_b(t_1)$  caused by ship-induced field, sensor drifting and sensor perturbation, all at time  $t_1$  and along track distance  $x$ , and at some later time  $t_2$ ,  $\Delta l$  is the distance between the sensors,  $D(t_2)$  is the diurnal variations sensed by the rear  
35 sensor, and

$M_b(t_2)$  is the ship bias at time  $t_2$  detected by the

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rear sensor  $M_r$ .

8. The method of claim 1 wherein the first and second sensors which are towed behind the ship are  
5 included in a group of three or more towed sensors.

9. The method of claim 8 wherein the number of sensors towed behind the ship comprises three sensors.

10 10. A method of obtaining gradient data for an exploration program, the method including:  
towing first and second sensors behind a ship along predetermined survey lines;  
obtaining raw magnetic gradient data from the  
15 sensors;  
determining the trend of the gradient of the ship bias detected by the sensors;  
subtracting the trend from the raw magnetic gradient data to obtain corrected gradient data; and  
20 processing the corrected gradient data to provide a data output.

11. The method of claim 10 wherein the method includes the step of determining an estimate of the  
25 gradient of the ship bias from the raw magnetic gradient data obtained by the sensors, and determining the trend of the gradient of the ship bias from that estimate of the gradient of the ship bias.

30 12. The method of claim 10 wherein the raw magnetic gradient data is calculated as the measured magnetic signal at the leading sensor less the measured magnetic signal at the trailing sensor, divided by the distance between the sensors.

35 13. The method of claim 10 wherein the trend of the gradient of the ship bias is determined by applying the

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gradient of the ship bias data to a B-Spline filter with smoothness 0.8.

14. The method of claim 10 wherein the further  
5 processing comprises the application of the corrected  
gradient data over sample intervals, integration of the  
corrected gradient data into total magnetic intensity  
data, and application of a low passed filter to the  
10 integrated total magnetic intensity data to provide the  
data output.

15. The method of claim 14 wherein the total magnetic  
intensity is obtained by integrating the corrected  
15 gradient data in accordance with the following equation:

$$TMI = \sum_{i=1}^N [G_c \Delta x_i(t)] + M_{stat}$$

wherein  $G_c$  is the corrected gradient data  
obtained after subtraction of the ship bias trend from the  
raw gradient data, and

20  $M_{stat}$  is the total magnetic intensity value at a  
point representing the start of the survey or at a  
location where a survey line and a tie line cross each  
other.

25 16. The method of claim 10 wherein the gradient of  
the ship bias is calculated according to the following  
equation:

$$G_{bias} = \frac{M_f(x) - M_r(x)}{\Delta l} = \frac{[D(t_1) - D(t_2)] + [M_b(t_1) - M_b(t_2)]}{\Delta l}$$

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where:

$$M_f(x) = M_e(x) + D(t_1) + M_b(t_1)$$

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$$M_r(x) = M_e(x) + D(t_2) + M_b(t_2)$$

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where  $M_f$  is the magnetic field as measured by the front sensor and which consists of the environmental field  $M_e(x)$ , diurnal variation  $D(t_1)$ , ship bias  $M_b(t_1)$  caused by ship-induced field, sensor drifting and sensor  
5 perturbation, all at time  $t_1$  and along track distance  $x$ , and at some later time  $t_2$ ,  $\Delta l$  is the distance between the sensors,  $D(t_2)$  is the diurnal variations sensed by the rear sensor, and

10  $M_b(t_2)$  is the ship bias at time  $t_2$  detected by the rear sensor  $M_r$ .

17. The method of claim 10 wherein the first and second sensors which are towed behind the ship are included in a group of three or more towed sensors.  
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18. The method of claim 17 wherein the number of sensors towed behind the ship comprises three sensors.

19. A method of subsurface exploration to determine  
20 viability of drilling in a marine environment by considering magnetic data relating to the environment, and wherein the magnetic data has been obtained by:

obtaining raw magnetic gradient data from a plurality of sensors;

25 determining the trend of the gradient of the ship bias detected by the sensors;

subtracting the trend from the raw magnetic gradient data to obtain corrected gradient data; and

30 processing the corrected gradient data to provide a data output.

20. The method of claim 19 wherein the magnetic data includes the step of determining the gradient of the ship bias from data obtained by the sensors, and determining  
35 the trend of the gradient of the ship bias from the gradient of the ship bias.

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21. The method of claim 19 wherein the raw magnetic gradient data is calculated as the measured magnetic signal at the leading sensor less the measured magnetic signal at the trailing sensor, divided by the distance  
5 between the sensors.

22. The method of claim 19 wherein the trend of the gradient of the ship bias is determined by applying the gradient of the ship bias data to a B-Spline filter with  
10 smoothness 0.8.

23. The method of claim 19 wherein the processing comprises the application of the corrected gradient data over sample intervals, integration of the corrected  
15 gradient data into total magnetic intensity data, and application of a low passed filter to the integrated total magnetic intensity data to provide the data output.

24. The method of claim 23 wherein the total magnetic intensity is obtained by integrating the corrected  
20 gradient data in accordance with the following equation:

$$TMI = \sum_{i=1}^N [G_c \Delta x_i(t)] + M_{stat}$$

wherein  $G_c$  is the corrected gradient data  
25 obtained after subtraction of the ship bias trend from the raw gradient data, and

$M_{stat}$  is the total magnetic intensity value at a point representing the start of the survey or at a location where a survey line and a tie line cross each  
30 other.

25. The method of claim 19 wherein the gradient of the ship bias is calculated according to the following equation:  
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$$G_{bias} = \frac{M_f(x) - M_r(x)}{\Delta l} = \frac{[D(t_1) - D(t_2)] + [M_b(t_1) - M_b(t_2)]}{\Delta l}$$

where:

$$M_f(x) = M_e(x) + D(t_1) + M_b(t_1)$$

$$M_r(x) = M_e(x) + D(t_2) + M_b(t_2)$$

where  $M_e$  is the magnetic field as measured by the front sensor and which consists of the environmental field  $M_e(x)$ , diurnal variation  $D(t_1)$ , ship bias  $M_b(t_1)$  caused by ship-induced field, sensor drifting and sensor perturbation, all at time  $t_1$  and along track distance  $x$ , and at some later time  $t_2$ ,  $\Delta l$  is the distance between the sensors,  $D(t_2)$  is the diurnal variations sensed by the rear sensor, and

$M_b(t_2)$  is the ship bias at time  $t_2$  detected by the rear sensor  $M_r$ .

26. The method of claim 19 wherein the number of sensors towed behind the ship comprises three sensors.

27. A method of drilling for a deposit in a marine environment, including:

determining the location of drilling from data which has been obtained and which indicates the possible existence of the deposit; and

which location is also determined by magnetic data which has been obtained by towing magnetic sensors behind a ship, the magnetic data being processed by:

obtaining raw magnetic gradient data from the sensors;

determining the trend of the gradient of the ship bias detected by the sensors;

subtracting the trend from the raw magnetic gradient data to obtain corrected gradient data; and

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processing the corrected gradient data to provide a data output.

28. The method of claim 27 wherein the method includes the step of determining an estimate of the gradient of the ship bias from the raw magnetic gradient data obtained by the sensors, and determining the trend of the gradient of the ship bias from that estimate of the gradient of the ship bias.

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29. The method of claim 27 wherein the raw magnetic gradient data is calculated as the measured magnetic signal at the leading sensor less the measured magnetic signal at the trailing sensor, divided by the distance between the sensors.

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30. The method of claim 27 wherein the trend of the gradient of the ship bias is determined by applying the gradient of the ship bias data to a B-Spline filter with smoothness 0.8.

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31. The method of claim 27 wherein the processing of the corrected gradient data comprises the application of the corrected gradient data over sample intervals, integration of the corrected gradient data into total magnetic intensity data, and application of a low passed filter to the integrated total magnetic intensity data to provide the data output.

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32. The method of claim 31 wherein the total magnetic intensity is obtained by integrating the corrected gradient data in accordance with the following equation:

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$$TMI = \sum_{i=1}^N [G_c \Delta x_i(t)] + M_{stat}$$

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wherein  $G_c$  is the corrected gradient data obtained after subtraction of the ship bias trend from the



raw gradient data, and

$M_{stat}$  is the total magnetic intensity value at a point representing the start of the survey or at a location where a survey line and a tie line cross each other.

33. The method of claim 27 wherein the gradient of the ship bias is calculated according to the following equation:

$$G_{bias} = \frac{M_f(x) - M_r(x)}{\Delta l} = \frac{[D(t_1) - D(t_2)] + [M_b(t_1) - M_b(t_2)]}{\Delta l}$$

where:

$$M_f(x) = M_e(x) + D(t_1) + M_b(t_1)$$

$$M_r(x) = M_e(x) + D(t_2) + M_b(t_2)$$

where  $M_f$  is the magnetic field as measured by the front sensor and which consists of the environmental field  $M_e(x)$ , diurnal variation  $D(t_1)$ , ship bias  $M_b(t_1)$  caused by ship-induced field, sensor drifting and sensor perturbation, all at time  $t_1$  and along track distance  $x$ , and at some later time  $t_2$ ,  $\Delta l$  is the distance between the sensors,  $D(t_2)$  is the diurnal variations sensed by the rear sensor, and

$M_b(t_2)$  is the ship bias at time  $t_2$  detected by the rear sensor  $M_r$ .

34. The method of claim 27 wherein the first and second sensors which are towed behind the ship are included in a group of three or more towed sensors.

35. The method of claim 34 wherein the number of sensors towed behind the ship comprises three sensors.

36. The method of claim 35 wherein data from any two

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of the sensors is used to provide the raw magnetic gradient data.